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Industry's technological needs and university research can be parallel paths along the road of scientific endeavor. But, opportunities for industrialists and academics to discuss technical problems and new concepts on a regular basis are limited. A unique solution to this dilemma can be found in Japan, in the form of the 'Industry-University Cooperative Research Committees', supported by the Japan Society for the Promotion of Science, (JSPS) to encourage scientists and engineers from industry and academia to meet regularly for face-to-face discussions about topics of common interest.

The JSPS 162 committee

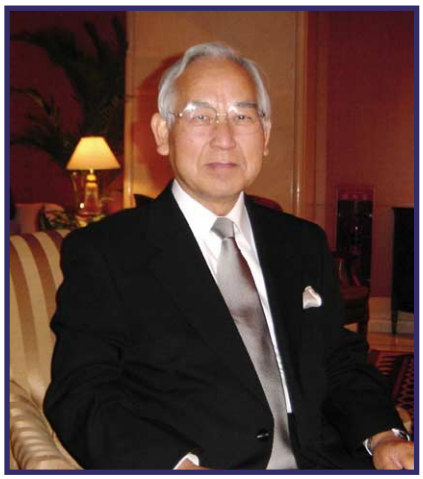


Fig.1 Professor Kiyoshi Takahashi, Chairman of the 162 Committee. Professor Takahashi is also Director R&D Center, Nippon EMC Ltd and emeritus Professor of Tokyo Institute of Technology.

In this article, Professor Kiyoshi Takahashi, Chairman of the JSPS "162 Committee," describes his committee' s activities on wide bandgap semiconductors (GaN, SiC and ZnO) and devices including blue LEDs and high frequency electronics, exemplified by AlGaN/GaN HEMT and SiC power transistors. The JSPS committees play an important role in the development of basic research into commercial products, and could be used as role models by other countries.

Background and rules

The JSPS was established in 1932 as a non-profit foundation and has abudget of ¥131bn for fiscal 2005. It is the largest funding agency in Japan, supporting university research and international scientific exchanges, such as the highly competitive JSPS post-doctoral fellowships.

The JSPS also invites and screens proposals for themes for new 'Industry-University Cooperative Research Committees.'

To date, about 177 such committees have been setup, with 155 committees currently active. In order to establish a committee, JSPS guidelines dictate equal numbers of members must come from industry and academia.

Industrial members are all obliged to support the running of the committee, with financial contributions of about ¥200,000 a year for each company.

Once a committee is approved, it is given a number; the larger the number the younger the committee. Each committee is required to renew its mandate every five years, which enables changes in direction and areas being studied.

In any given year, a typical committee will (1) organise five to six domestic technical meetings and seminars for its members to meet and discuss the hot topics of the day; (2) organise and sponsor international symposia and conferences; (3) disseminate information about their activities via technical publications and proceedings of technical meetings, that are available to the general public.

JSPS '162'

This Committee was established in April 1996, with about 80 members, to focus on developments on 'Short-Wavelength Opto-electronic Devices'.

This topic was chosen because in 1996, GaN based devices were seen as being likely to replace II-VI semiconductors for fabrication of UV optical devices for optical information storage and solid state full colour displays.

In 2001, during the Committee' s 2nd term, the emphasis shifted to discussions on ' Wide Band Gap Semiconductors and Electronic Devices', which included materials used in power electronics such as SiC and nitride HEMT structures.

For the 3rd term, scheduled to start in April 2006, the 162 Committee will concentrate on 'Wide Bandgap Semiconductors and Opto-electronic Devices', in particular InN/GaN-based semiconductors, SiC, ZnO, diamond and II-VI materials.

These materials are seen as being important in the development of LEDs for white lighting; short wavelength optical devices for bio-sensing and high density information storage; high power/high output devices for vehicles such as

electric cars; and terabit optical communications.

Achievements and activities

Professor Kiyoshi Takahashi (Fig.1), recently appointed director of the R&D Center of Nippon EMC Ltd, is also emeritus professor of the Tokyo Institute of Technology and has been the chairman of the 162 committee since its inception in 1996.

During an illustrious career, Professor Takahashi has worked on a wide range of semiconducting materials and devices, including thin film solar cells, GaAs/AlGaAs HBTs grown by MOMBE, II-VI optical devices, and more recently, growth of GaN devices by RF-MBE.

Fig. 2: Joint German-Japan (162 Committee) workshop, Berlin (1997). Professor Takahashi and Professor Ploog, PDI.

He recalls that, "in the early 1990's there was a lot of interest in nitride compound semiconductors, following the breakthroughs by Professor Isamu Akasaki and Dr Shuji Nakamura, but the people involved did not have many opportunities to meet and discuss issues related to materials and devices.

"So the JSPS ' 162 Committee' was set-up as a forum, to help clarify the problems faced by industry, and encourage universities to conduct research on solving these problems."

Under Professor Takahashi' s leadership, the '162 Committee' has organised regular domestic meetings as well as international workshops, initially organised with colleagues in Germany, including Professor Klauss Ploog of the Paul Drude Institute, Berlin (Fig.2).

Later this extended to meetings organised with the nitrides communities from China, Taiwan and Korea (Fig.3), as part of the Asia-Pacific WideGap Semiconductor Workshops (APWS) series.

The '162 Committee' has also organised international conferences and symposia including, International Symposium on Blue Laser and Light Emitting Diodes (ISLLED) with an inaugural meeting in Chiba (1996) with the latest meeting scheduled for Montpellier in 2006.

Conferences have included, the 5th International Conference on Nitride Semiconductors in Nara (May 2003), with plans for the International Conference on Metalorganic Vapour Phase Epitaxy (ICMOVPE) in Miyazaki (May 2006), and the International Workshop Nitride Semi-conductors (IWN) in Kyoto (October 2006).

The industrial members of the 162 Committee are affiliated with internationally known companies, including Sony, Sharp, Hitachi, Toshiba and Nichia. Japanese industry has made tremendous contributions to nitrides research, and its commercialisation. A recent example is white light LEDs, which use less power and have longer lifetimes than incandescent bulbs.

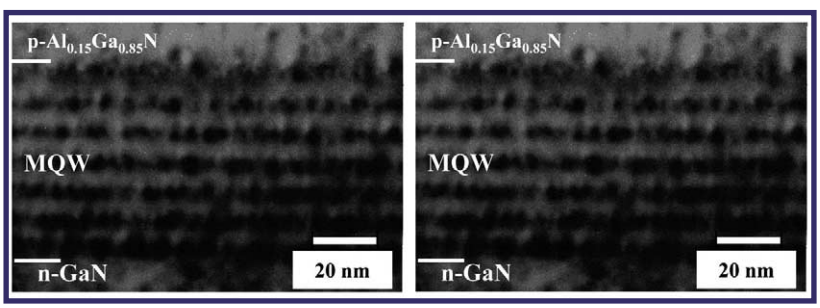
Professor Takahashi reflects that, "one of the most dramatic changes in peoples lifestyles will be due to ' white light' produced using a combination of nitride LEDs and phosphors. With the increasing wide spread use of white LED lighting, we have moved from Edison's 'analog lighting' to 'digital lighting'.

"Lighting was historically used for illuminating dark areas on streets and in houses, but nowadays lighting can be thought of more as 'artificial make-up' that can be tuned to suit our needs. I think that development of technology by Professor Akasaki in 1989 to produce pn junctions in GaN, was a critical step in the evolution of white LEDs; equivalent to the transition of vacuum tube technology to solid states circuits in the 1950s."

In 1997, university based members of the '162 Committee' discovered that self-forming In-rich

Fig. 3: Participants of the joint Korea-Japan Workshop (1998).

Fig. 4: Cross sectional transmission electron micrograph [0110] 0002 bright field image of InGaN multi-quantum wells. The dark spots are In-rich dots with a diameter of 3nm.



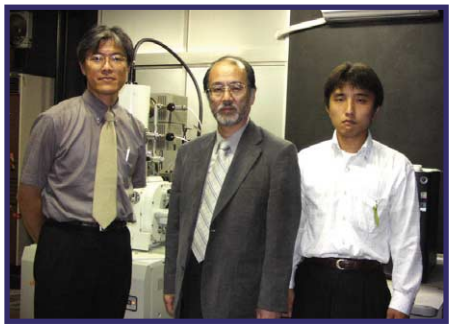


Fig. 5: The Chiba University Group central to the running of the 162 Committee. Professor Akihiko Yoshimura (center), Associate Professor Yoshihiro Ishitani (left) and Dr Song-Bek Che (right).

quantum dots in AlGaN/InGaN quantum well structures enhance the optical emission efficiency in such structures [1]. The dark spots in the TEM image of Fig. 4 are In-rich dots of about 3nm in diameter and with a real density of $5x10^{11}$-$2x10^{12}cm^{-2}$. Injected carriers are localised into these dots which results in high efficiency optical emission.

Professor Akihiko Yoshikawa of Chiba University has been a central figure of the '162 Committee' since 1996. His group has developed an RF-MBE system fitted with spectroscopic ellipsometry, RHEED and coaxial impact collision ion scattering (CAICISS) for real-time monitoring and control of the polarity of InN and GaN surfaces [Fig.6].

An in-depth knowledge of growth parameters has enabled Professor Yoshikawa' s group to grow, high quality, 5-10µm thick epitaxial InN layers on sapphire surfaces and novel InN columns [Fig.6]. Their goal is to investigate InN/GaN, InN/InGaN and InN/InAlN heterostructures covering the whole band-gap range between InN and AlN for optoelectronic and modulation doped devices [2,3].

Research funding

Needless to say, members of the '162 Committee' compete for funding from a range of sources. University research funding in Japan has seen some subtle, but important, changes over the last few years, with the main emphasis being on prioritising areas and funding collaborative research with large grants, as opposed to the uniform distribution of smaller funds, that was prevalent several years ago.

The main funding agencies are JSPS, Japan Society and Technology Agency (JST) and New Energy and Industry Technology Development Organization (NEDO), that are in charge of implementing and managing budgets allocated by government ministries.

Japan's R&D funding for fiscal 2005 is: Life Sciences $4.51bn; Information & Communication $4.06bn; Environment $1.49bn; Nanotechnology and Nano-materials $0.97bn.

Priority areas in the future are post-Genome, new and reconstruction infectious disease, ubiquitous network, next-generation robotics, bio-mass, hydrogen utilisation and fuel cell, nano-bio technology, and local area S&T clusters.

Persistence

The JSPS Industry-University Research Committees have, and will continue to play, a valuable role in the development of technology, both in Japan and ultimately globally. It' s not clear if a similar approach would work in other countries, but Professor Takahashi thinks that, "major advances in science are the results of hard work and persistence.

"For example, Shockley' s ideas for the transistor were not initially taken seriously by other scientists, but his continued efforts paid off in the end. Similarly, Professor Akasaki worked for many years before producing p-type GaN. I would call their inventions, 'persistors'!

"The 162 committee has been a catalyst and trigger for innovation in this field. But ultimately, it is the individuals' determination to continue, often in directions that defy the wisdom of the day, which is important for technological evolution."

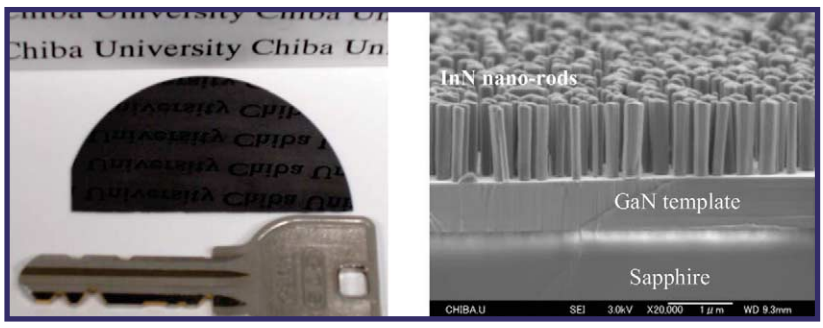


Fig 6. 5-10micrometer thick epitaxial InN layers on sapphire surfaces (left) and novel InN columns (right).

Further information

Technical publications:

1. Y. Narukawa et.al, "Role of self formed InGaN quantum dots for excition localization in the purple laser emitting at 420nm", *Appl. Phys. Lett.*, 70, pp.981-983, (1997).

2. X.Wang and A.Yoshikawa,"Molecular beam epitaxy growth of GaN, AlN and InN" *Progress in Crystal Growth & Characterization of Materials*, 48-49, pp.42-103, (2005).

3. S.B.Che, W.Terashima, Y.Ishitani, T,Matsuda, H.Ishii, S.Yoshida and A.Yoshikawa,"Fine structure N-polarity InN/InGaN multiple quantum wells grown on GaN underlayer by molecular-beam epitaxy", *Appl. Phys. Lett.*, 86, pp. 261903-261906, (2005).

Websites

Nippon EMC Ltd: http://www.n-emc.co.jp/

Chiba University: http://www.chiba-u.ac.jp/e/index.html

ICMOVPE : http://icmovpe13.chem.tuat.ac.jp//

IWN: http://www.iwn2006.org/

Japan Society for the Promotion of Science (JSPS): http://www.jsps.go.jp/english/index.html

Japan Science and Technology agency (JST): http://www.jst.go.jp/EN/index.html

The New Energy and Industrial Technology Development Organization (NEDO): http://www.nedo.go.jp/english/index.html